A BENTHIC STUDY OF THE AVON SPRING STREAM, CHRISTCHURCH

J.W. MARSHALL,

Department of Zoology, University of Canterbury,
Christchurch, New Zealand.

ABSTRACT

The Avon Stream arises from one helocrene and four rheocrene springs. These have a constant flow into a small moderately fast stream with a bed of clay, mud and patches of weed. Oxygen, temperature, pH, cross sectional area and flow were measured in conjunction with biological sampling. Oxygen saturation of the spring water was constant at 51% while downstream it showed a diel fluctuation. Animal density ranged from 100-500/0.1 m^2. Oligochaeta, Amphipoda and Mollusca were the most abundant faunal groups while Platyhelminthes were noticeably less common. A dilution technique for increasing counting accuracy is described. A biotope for the spring stream is proposed.

INTRODUCTION

In recent years there has been considerable interest in the biology of cold springs notably by Odum (1957), Teal (1957) and Tilly (1968), while others have been concerned with the faunal characteristics of spring-fed streams (Minckley 1963, Minshall 1968). The effects of chemical and physical variations on the biology of smaller springs has been investigated by Noel (1954) and Tuxen (1944).

In New Zealand there is a dearth of literature on the biology of springs except for recent studies on hot springs (Winterbourn 1968, 1969). Studies on cold springs include the geological investigation of Henderson (1928) on the Waikoropupu Springs, Nelson province, a study by Johnstone (1969) on Western Springs, Auckland, and an as yet uncompleted study by Wells on the biology of the Waikoropupu Springs. No studies have been made on small soft bottom spring streams. This paper describes an investigation of such a stream type, with emphasis on the interaction of the substrate with the fauna and the changes in the fauna downstream from the springs. Seasonal influences and life histories were not considered in this short term study.

DESCRIPTION OF THE STUDY AREA

The study area (Fig. 1) comprised the first 60 m of the Avon River Spring stream, grid reference N.Z.M.S. L.S.584 950 572. The stream arises in a manner typical of most streams around Christchurch. Woods (pers. comm.) suggests a common source from the aquifers of the fluvial Waimakariri shingles which come into contact with overlying and less permeable marine deposited clays and sands of the East coast. At this junction springs of the rheocrene and helocrene types occur. Limnocrenes have not been

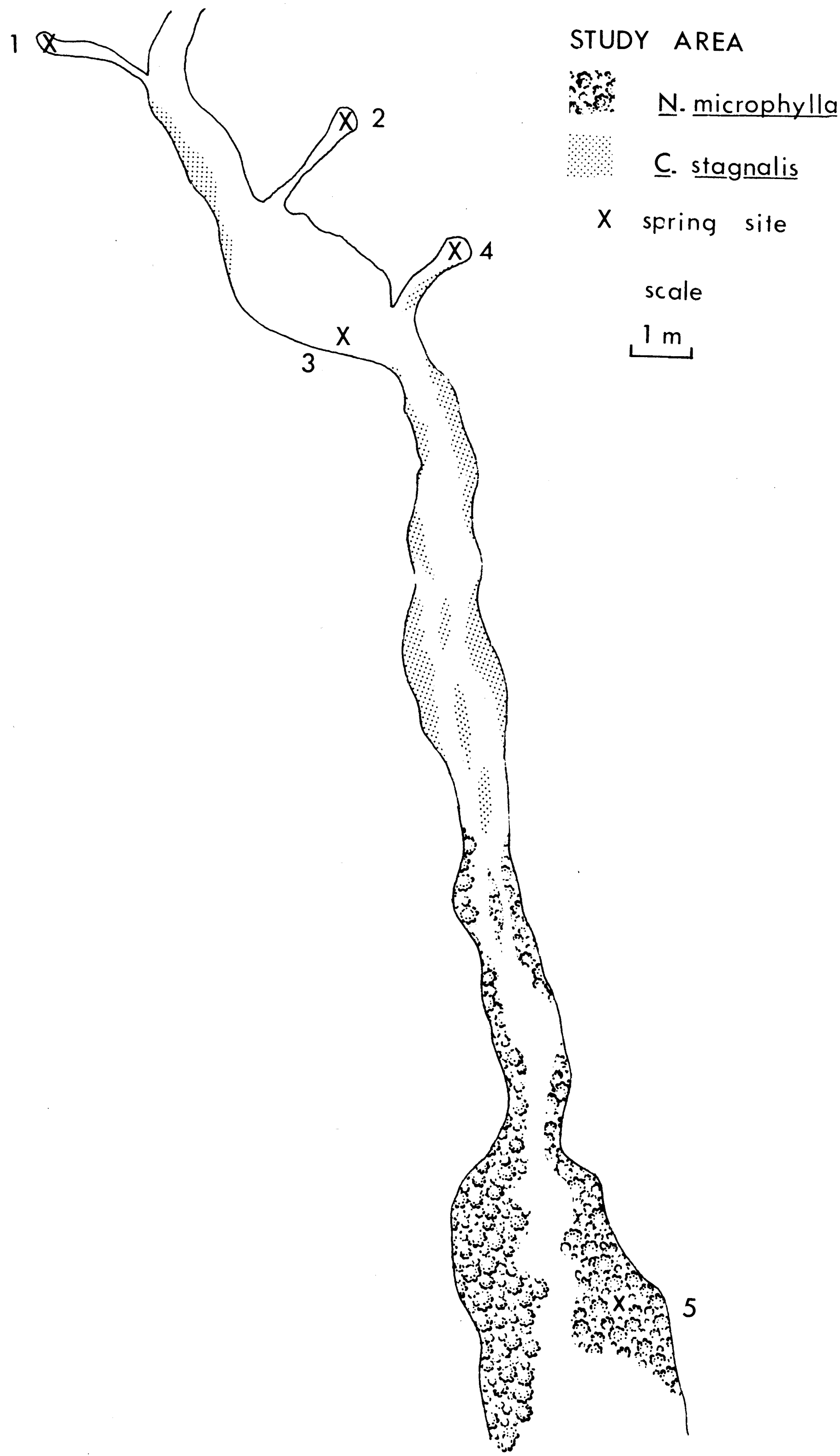

Fig. 1. The study area showing the positions of the five spring vents and the vegetation pattern.

observed. These three spring types are defined below following Noel (1954).

Rheocrene: arise as torrents and flow rapidly away; they do not form pools.
Helocrene: arise from seepage in marshy or boggy areas; no well defined vent.
Limnocrene: form sizeable pools before running into streams.

Other terms used in the description of springs are:

Head: the difference of convexity of the water against a fixed point.
Vent: the actual area where the water comes to the surface.
Flow Channel: the channel that connects the spring vent to the main stream.

All the springs studied, one helocrene and four rheocrenes, flow into a common stream (Fig. 1). The rheocrenes are grouped together approximately 2 m apart and the helocrene (Fig. 2, spring 5) is situated 58 m downstream. The stream is set in a gully 3 m deep.

DESCRIPTION OF SPRINGS AND STREAM

The main features of the springs and their relationship to the main stream are summarised in Table 1.

TABLE 1. THE MAIN FEATURES OF THE SPRINGS AND THEIR RELATIONSHIP TO THE MAIN STREAM

Spring no.	Relation to main stream	Type of spring	Vent diameter (m)	Depth of spring (m)	Surrounding vegetation
1	Connected by ill-defined channels	rheocrene	0.4	0.2	Salix sp.
2	Connected by 2 m channel 0.2 x 0.18 m	rheocrene	0.18	0.3	overhanging Agrostis stolonifera
3	In stream bed	rheocrene	0.13	0.4	-
4	Connected by 0.5 m channel 0.34 x 0.25 m	rheocrene	0.50	0.81	overhanging A. stolonifera with Callitriche in channel
5	Ill-defined dendritic channels under watercress	helocrene	diffuse seepage	-	completely obscured by pad of watercress

The springs maintain a continuous flow and are part of a larger old spring system which was 1 km upstream from the present source. Urbanisation in the area has lowered the water table so that the larger springs are now dry. Stream flow is fairly constant and not subject to rainfall in distant catchments. This is indicated by the very slight variation in the spring head. Local storm waters which flow into the dry upstream bed have a

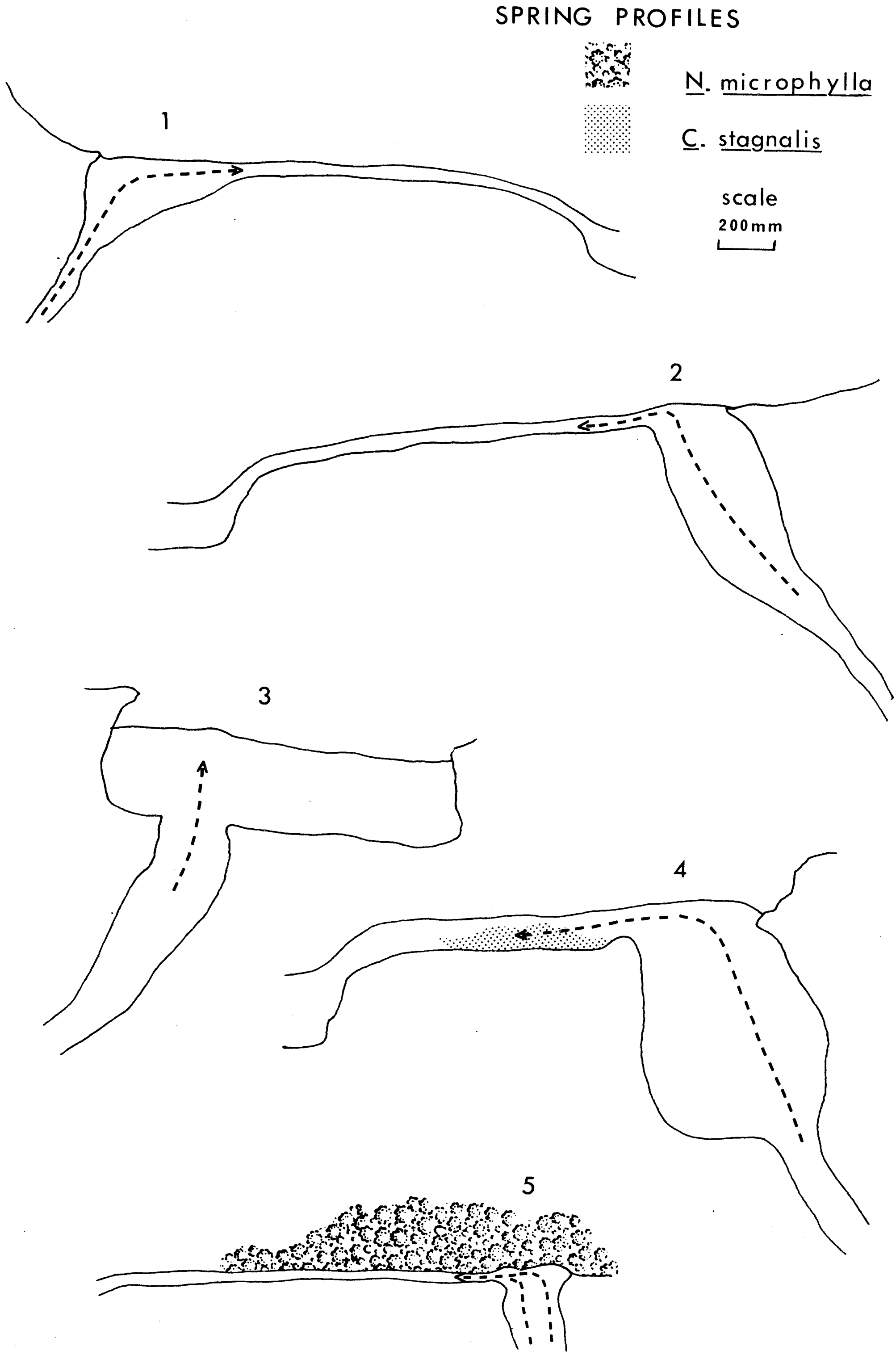

Fig. 2. The profiles of the rheocrene (springs 1-4) and helocrene (spring 5) springs showing the nature of the vents.

significant effect on the stream bed, however, and are the source of most of the detritus which accumulates there. Oak leaves (*Quercus* sp.) from trees 1 km away, and twigs and grass were common in the stream.

The stream itself is moderately fast flowing and has a steep sided channel. At the confluence of the three major springs there is a "pooling" of the waters (Fig. 1). The stream channel narrows to 0.32 m and maintains this width for the next 40 m. The bottom of this section is firm clay with a little accumulated sand and detritus around the roots of the plants, *Callitricha stagnalis* and *Agrostis stolonifera*. In the lower 20 m of the section studied the stream widens to 3.5 m and flows more slowly over a shallow bed of fine muds, sand and detritus on which an extensive mat of *Nasturtium microphylla* grows.

METHODS

The study area (Fig. 1) was sampled at 2 m intervals during August 1971, and physico-chemical and biological parameters were measured.

PHYSICO-CHEMICAL

Flow rates were estimated by the cork float method and discharge was calculated from this value times the cross sectional area of the stream. The constancy of the discharge was estimated by differences in the water level against a fixed marker. Temperature was taken 0.1 m below the water surface with a hand held mercury thermometer. The stream substrate was described according to firmness, fineness and amount of detritus. Dissolved oxygen was determined by the Standard Winkler method over 24 hours at spring no. 4 and 60 m downstream from that spring. *pH* was measured with a "Metrohm 866" *pH* meter.

BIOLOGICAL

Sampling sites were divided into stream bed, floating vegetation and springs for comparison. The stream was accessible in waders and a 0.1 m^2 sample was collected at each site with a hand-held Wisconsin sampler. The net size of the retaining bag was 0.25 mm.

To remove the mud and weed the sample was washed through a series of "Endecott" sieves (7.96, 1.00, 0.355 mm).

Animals in the samples were counted alive using the dilution technique described below.

Dilution technique

1. The sample was placed in a large sorting tray with water.
2. Subsamples were sluiced into a smaller tray and counted.

This process was repeated for the whole sample as selected subsampling was not considered satisfactory due to the heterogeneous nature of the sample. Using this method a greater degree of accuracy was obtained, than could be obtained without diluting the sample (Table 2). This particularly applied to the sorting and counting of oligochaetes.

TABLE 2. COMPARISON OF NUMBERS COUNTED USING DIFFERENT METHODS

	DILUTED						UNDILUTED					
Sample No.	Tub.	Lumb.	Pot.	Phys.	Amphi.	Tip.	Tub.	Lumb.	Pot.	Phys.	Amphi.	Tip.
1	194	252	11	15	6	33	106	91	11	12	3	25
2	200	288	11	15	4	33	84	40	11	15	6	29
3	169	232	11	14	6	31	119	82	10	12	4	31
4	187	271	11	15	6	30	160	196	11	12	2	26
5	179	265	11	13	7	33	96	103	11	13	1	19
$\bar{x}$	185.8	261.6	11.0	14.4	5.8	32.0	113.0	102.4	10.9	12.8	3.2	26.0
$s_{\bar{y}}$	4.8	8.0	0.0	0.4	0.4	0.5	11.7	22.9	0.2	0.5	0.8	1.8

Abbreviations in the table:

Tub. = Tubificidae.
Pot. = *Potamopyrgus antipodarum*.
Amphi. = *Paracalliope fluviatilus*.
Lumb. = Lumbriculidae.
Phys. = *Physa* sp.
Tip. = Tipulidae.

Each species extracted from benthic samples was expressed as total numbers/0.1 m^2, and as percentage composition. Each species in the weed samples was expressed as total numbers/10 g dry weight of weed. Weed dry weight was determined after oven drying at 100°C for three days.

RESULTS

STREAM FLOW

Flow rates, stream profile and discharge rates of the springs and sections of the stream are shown in Table 3.

TABLE 3. MEAN VELOCITY, DEPTH, WIDTH AND CALCULATED DISCHARGE RATES IN THE SPRINGS AND SPRING STREAM

Stations	Mean velocity (m/sec)	Mean width (m)	Mean depth (m)	Calculated discharge (m^3/sec)
Spring 1	-	-	-	16*
Spring 2 channel	0.5	0.20	0.18	18
Spring 3	-	-	-	16*
Spring 4 channel	0.3	0.34	0.25	25
"Pool"	0.3	1.00	0.30	75
Station 15	0.7	0.32	0.28	69
Spring 5	-	-	-	1*
Station 2	0.2	3.50	0.10	70

* rate determined by difference

Because of weed growth in the channels and the method of determining water velocity the figures in the table must be considered approximate.

The level of the spring "head" was 20 mm above the water level.

The temperature of the spring water was stable (12-13°C), from June to September. This is consistent with spring streams of a similar type elsewhere, e.g., Minckley (1963), Doe Run Kentucky (13.3°C); Minshall (1967), Morgans Creek (9.8-14.0°C); Stern and Stern (1969), unnamed stream in Monterey (11.2-15.8°C); and places the stream within the definition of a true spring stream (Berg 1951).

Fowles (1969), working downstream from the study area in the Ilam stream, noted a range of 11.0-14.0°C during the same months in 1969 indicating only slight warming with distance travelled.

DISSOLVED OXYGEN AND *pH*

Percentage saturation in the stream was not high and in spring no. 4 remained constant at 51% saturation throughout a diel sampling period. The downstream station during the same cycle increased to a maximum of 54% at 1500 hr and dropped to 51.5% at 0300 hr. The observed increase during the day can probably be accounted for by the photosynthetic activity of submerged weeds. *C. stagnalis* had noticeable bubbles of gas at the base of each leaf during the day.

pH was a constant 7.3 at all stations.

FAUNA

Five species of invertebrates frequently occurred in high numbers while another six species were less common (Table 4).

TABLE 4. INVERTEBRATES FOUND IN THE SPRING STREAM

More common	Less common
Tubificidae (Oligochaeta)	Cura pinguis (Turbellaria)
Lumbriculus variegatus (Oligochaeta)	Pisidium sp. (Pelecypoda)
Physa sp. (Gastropoda)	Chironomidae larvae
Potomopyrgus antipodarum (Gastropoda)	Liodessus plicatus (Dytiscidae)
Paracalliope fluviatilus (Amphipoda)	Tipulidae larvae
	Simuliidae pupae and adults

Bottom samples

The total number of animals collected in each sample fluctuated between 100-500/0.1 m^2 and the percentage composition varied between stations.

The major taxa, which made up more than 90% of the total fauna present, exhibited the following trends:

(i) Tubificidae: The percentage composition varied throughout the length of the stream and the highest percentage (80%) occurred in fine muds and detritus, at a density of 300/0.1 m^2. In coarse detritus they accounted for only 50% (100/0.1 m^2) and in the shingle area they were reduced to 10% (25-30/0.1 m^2) of the total fauna.

It appeared that Tubificidae had a preference for fine muds and detritus which could provide the greatest amount of available food. When this food source was lacking, as in the shingle areas, numbers of Tubificidae declined. Their low numbers amongst coarse allochthonous detritus (leaves and twigs) was possibly due to the inadequate decomposition of this detritus to provide an available food source.

(ii) *Lumbriculus variegatus*: This species constituted 30-40% of all samples. Total numbers varied considerably (20-200/0.1 m^2) and these variations were similar to those found for Tubificidae. Where Tubificidae were in high numbers, *L. variegatus* were also high.

There was a tendency for a higher percentage of *L. variegatus* to appear in coarse detritus, while the presence of fine detritus increased the numbers of *L. variegatus* and Tubificidae, without altering the relative percentage of *L. variegatus*. These substrate preferences have also been observed by other workers. For example, Minckley (1963) observed the presence of *Lumbriculus* sp. where leaf matter was present, and Noel (1954) and Ball et al (1969) found that the highest numbers of Tubificidae were in black organic mud.

(iii) Mollusca: Total molluscan fauna was low throughout the sampled sections and was composed of small numbers (10-25/0.1 m^2) of *Physa* sp., *Potamopyrgus antipodarum* and *Pisidium* sp. In slower water the distribution of this group was marked by a sharp increase in numbers. Faster water supported fewer animals. Noel (1954) in New Mexico suggested that it is current that limits *Physa* and this could well apply to *Physa* in the Avon Spring stream.

(iv) *Paracalliope fluviatilus*: This amphipod was present for the most part in small numbers (50/0.1 m^2) and represented 10% of the total fauna. When larger numbers (100-125/0.1 m^2) occurred the substrate changed from mud to weed. High numbers were found where rooted plant material was present. This has been noted by Stout (1968) and Hirsch (1958). Upstream stations had a shingle substrate (10-20 mm stones) and rooted *C. stagnalis*. This apparently gave rise to a habitat suitable for amphipods in the interstices of the gravel as noted by Minckley (1963). In these conditions *P. fluviatilis* was most common (100-125/0.1 m^2) making its highest (30-70%) contribution to the fauna.

Other groups were present in very low numbers:

(i) Chironomid larvae were present along the length of the stream with a downstream increase from 2-10/0.1 m^2.

(ii) Tipulid larvae were confined to areas of coarser detritus where they averaged 2/0.1 m^2.

(iii) The dytiscid beetle, *Liodessus plicatus*, was found in low numbers (2-4/0.1 m^2) and was confined to open shingle and *C. stagnalis* in the upstream area. A similar restricted distribution was noted for simuliid pupae.

(iv) Platyhelminthes, which are normally characteristic of spring streams, were noticeably absent. However, Noel (1954), Minckley (1963), Thorup (1964), and Stern and Stern (1969) found that flatworms favoured hard substrates. The muddy substrate of the Avon Spring stream appeared to be generally unfavourable for them.

Weed samples

There appeared to be little difference between habitats provided by the two weed species (*C. stagnalis* and *R. microphylla* since the same faunal groups were present in similar numbers and percentage composition on both plants (Table 5).

In both habitats *P. fluviatilis* was the dominant animal and made up 70-90% of the total numbers. Mean numbers/10 g dry weight weed were 111.0 ± *S.E.*18.0 on *R. microphylla* and 163 ± *S.E.*14.0 on *C. stagnalis*. The large standard errors may have

TABLE 5. MEAN NUMBER OF ORGANISMS FOUND ON TWO AQUATIC PLANT SPECIES. Results expressed as no./10 g dry weed

	C. stagnalis			*R. microphylla*		
	Number of samples	$\bar{x}$	*S.E.*	Number of samples	$\bar{x}$	*S.E.*
Cura pinguis	9	1.3	0.2	7	1.5	0.4
Gastropoda	11	9.3	1.5	9	14.1	4.0
Paracalliope fluviatilis	14	163.0	14.0	9	111.0	18.0

been due to clumping of animals in areas that were not subjected to a swift current. Also their high degree of mobility could have allowed some active avoidance of the Wisconsin net.

Mollusca, represented by *Potamopyrgus antipodarum* and *Physa* sp., were second in abundance to *P. fluviatilis*. The larger numbers on *R. microphylla* may be explained by the lower current velocity found where *R. microphylla* was present.

The triclad, *Cura pinguis*, occurred regularly in similar numbers on both vegetation types.

Spring samples

Few animals were present in the vents of the springs examined but a marked increase in numbers occurred in the flow channels. On entering the main stream numbers generally decreased again. The variation in numbers may be explained in terms of substrate type and water velocity.

The small size of the springs and their flow channels made it difficult to operate the sampler and therefore the resultant figures should be taken as an indication of relative abundance rather than actual numbers (Table 6).

Spring Number 1: This spring was not sampled because of the presence of human faecal matter.

Spring Number 2: A dense marginal growth of *A. stolonifera* which covered the spring did not contain any detritus or rooted matter. High numbers of Amphipoda similar to those at other weed stations were found in the vent and the channel.

Spring Number 3: The spring arose in the stream bed and was surrounded by coarse allochthonous detritus. Tubificidae, *L. variegatus* and *P. fluviatilus* occurred in low numbers around the vent.

Spring Number 4: This was the only spring with a definite vent floor (Fig. 2) and it supported high numbers of Tubificidae in the clay and detritus. The flow channel contained floating *C. stagnalis*, and large numbers of Amphipoda were present. The swiftness of the current had scoured out the bottom sediments and few animals were collected from it.

TABLE 6. INVERTEBRATES FOUND IN THE SPRINGS AND FLOW CHANNELS

Spring no.	2		3		4		5	
Species	C	S	C	S	C	S	C	S
<u>P. fluviatilus</u>	90	50	-	15	60	8	-	50
Tubificidae	-	-	-	9	-	60	211	94
<u>L. variegatus</u>	1	-	-	17	-	19	178	81
<u>P. antipodarum</u>	-	-	-	-	-	-	10	4
<u>Pisidium</u> sp.	-	-	-	-	-	4	6	2
<u>Physa</u> sp.	-	-	-	-	-	-	3	6

C = channel S = spring

Spring Number 5: Being the only helocrene spring in the study area, it had a slow flow through a dense mat of fine mud and *N. microphylla* stalks. The actual area of upwelling water did not leach out all the finer muds and probably for this reason larger numbers of animals were present than in the rheocrenes. Numbers increased further away from the spring and the percentage composition was similar to that at other fine detritus and mud stations.

DISCUSSION

The Avon Spring biotope (community) had a moderate to high number of Oligochaeta in the sediments and a similarly high number of Amphipoda in the weeds. Other species of animals were present in lower numbers and distributed along the bed according to habitat preferences. Substrate types ranged from firm to soft muds and detritus, while stream velocity ranged from moderate to slow. The stream was not subject to great changes in temperature and oxygen concentration. This biotope expressed in terms of characteristic elements, is not described by fixed faunal composition but rather by a basic assemblage that was modified by substrate and water velocity. These result in a faunal composition which best fits the existing conditions. This modifying effect can be seen in the following generalisations

1. Spring vents with fast flowing water had little detritus, mud or rooted matter and low numbers of Oligochaeta, Gastropoda, Amphipoda and Simuliidae.

2. The moderately fast flowing narrow stream with extensive weed cover (*C. stagnalis*) and a firm mud bottom supported moderate numbers of benthic Oligochaeta and in the weeds a similar number of Amphipoda. Mollusca numbers also increased.

3. In slow moving currents *N. microphylla* grew and thick layers of detritus and mud accumulated around it. The weeds supported moderate numbers of Gastropoda and Amphipoda. In the sediment, high numbers of Oligochaeta were found.

ACKNOWLEDGMENTS

I wish to thank Dr M.J. Winterbourn for his helpful criticism and suggestions, and Dr V.M. Stout for her support without which I would not have been able to carry out this study.

LITERATURE CITED

ALLEN, K.R. 1958. Distribution of stream bottom faunas. Proceedings of the New Zealand Ecological Society 6: 5-8.

BALL, R.C., KEVERN, N.R., LINTON, K.J. 1969. The Red Cedar River report II. Bioecology. Publications of the Museum Michigan State University Biological Series 4: 107-158.

BERG, K. 1951. Notes on some large Danish Springs. Hydrobiologia 3: 72-78.

FOWLES, C. 1969. A study of substrate fauna relationships in the Ilam stream. Unpub. M.Sc. project, University of Canterbury, New Zealand.

HENDERSON, J. 1928. Pupu Springs, Takaka. New Zealand Journal of Science and Technology 10: 111-115.

HIRSCH, A. 1958. Biological evaluation of organic pollution in N.Z. streams. New Zealand Journal of Science 1: 500-553.

JOHNSTONE, I. 1969. Control of Salvinia on Western Springs. Unpub. M.Sc. thesis, Auckland University, New Zealand.

MINCKLEY, W.L. 1963. The ecology of a spring stream Doe Run Meade County Kentucky. Wildlife Monographs 11: 1-124.

MINSHALL, G.W. 1968. Community dynamics of the benthic fauna in a woodland spring brook. Hydrobiologia 32: 305-339.

NOEL, M.S. 1954. Animal ecology of a New Mexico spring-brook. Hydrobiologia 6: 120-135.

ODUM, H.T. 1957. Trophic structure and productivity of Silver Springs, Florida. Ecological Monographs 27: 55-112.

STERN, M.S., and STERN, D.H. 1969. A limnological study of a Tennessee cold springbrook. American Midland Naturalist 82: 68-82.

STOUT, V.M. 1968. The invertebrate fauna of rivers and streams. In: Knox, G.A. (Ed.), The natural history of Canterbury, Royal Society of New Zealand: 471-497. Reed, Wellington. 620 pp.

TEAL, J.M. 1957. Community metabolism in a temperate cold spring. Ecological Monographs 27: 283-302.

THORUP, J. 1964. Substrate type and its value as a basis for the delimitation of bottom fauna communities in running water. Organism - substrate relationships in streams. Pymatuning Symposia in Ecology Special Publication Number 4: 59-75.

TILLY, J.L. 1968. The structure and dynamics of Cone Spring. Ecological Monographs 38: 120-197.

TUXEN, S.L. 1944. The hot springs of Iceland, their animal communities and their zoogeographical significance. In: The Zoology of Iceland, Volume I, part 2. Munksgaard Publ., Copenhagen.

WINTERBOURN, M.J. 1968. The faunas of thermal waters in New Zealand. Tuatara 16: 111-122.

——————— 1969. The distribution of algae and insects in hot springs thermal gradients at Waimangu, New Zealand. New Zealand Journal of Marine and Freshwater Research 3: 459-465.